REMARKS

Claims 1-3 are pending in this application, of which claim 1 is independent. Of those claims, claim 3 has been withdrawn from consideration pursuant to the provisions of 37 C.F.R. §1.142(b). In this Amendment, claim 1 has been amended to clarify the present invention. Care has been exercised to avoid the introduction of new matter.

Specification

A new title of the invention has been required. In response, the title has been amended in a manner suggested by the Examiner. Withdrawal of the objection to the specification is, therefore, respectfully solicited.

Claim objections

Claims 1 and 2 have been objected to because the phrase "its periphery fixed to the bobbin" is purportedly unclear.

In response, claim 1 has been amended to replace the phrase with --an inner periphery fixed to the bobbin--. Applicant respectfully solicits withdrawal of the objection to claims 1 and 2.

Claims 1 and 2 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Sato in view of Kan et al.

In the statement of the rejection, the Examiner admitted that Sato does not teach an ultrasonic complex vibration welding to fix components of a speaker to each other. However, the Examiner asserted that Kan et al. teaches the missing feature of Sato, and concluded that it

would have been obvious to apply the ultrasonic complex vibration welding taught by Kan et al. to Sato to arrive at the claimed invention. This rejection is respectfully traversed.

Applicant submits that the Examiner has not established a *prima facie* basis to deny patentability to the claimed invention under 35 U.S.C. §103 for lack of the requisite factual basis. To establish *prima facie* obviousness of a claimed invention, all the claim limitations must be taught or suggested by the prior art. *In re Royka*, 490 F.2d 981, 180 USPQ 580 (CCPA 1974).

Sato and Kan et al., either individually or in combination, do not teach a manufacturing method of a speaker including all the limitations recited in independent claim 1. Specifically, the applied combination does not teach, at a minimum, application of ultrasonic complex vibration welding to processes of fixing components of a speaker to each other.

As indicated in the Office Action, Sato does not teach the ultrasonic complex vibration welding. However, the Examiner identified the ultrasonic vibration described in Kan et al. as the claimed ultrasonic complex vibration welding. For example, Kan et al. describes as follows:

> Next, a horn of an ultrasonic welder (not shown) is pressed against the flange 26 of the objective lens 17 on the side opposite to the protrusions 27 and ultrasonic vibration is generated under pressure. By a complex action of the pressure and the ultrasonic vibration, the protrusions 27 are melted so that the objective lens 17 is welded to the lens holder 25....

Paragraph [0034] of Kan et al. According to the above description, Kan et al. applies pressure and ultrasonic vibration to components to be fixed to each other.

However, the complex action of the pressure and the ultrasonic vibration described in Kan et al. is different from the ultrasonic complex vibration used in the claimed invention. The ultrasonic complex vibration includes a plurality of ultrasonic vibrations each being oriented in a direction different from others', and each having a wavelength different from others' (see claim

2, and attached publications). Accordingly, it is apparent that Kan et al. does not teach the claimed ultrasonic complex vibration.

As described in the specification of the present application, there is a speaker manufacturing method utilizing ultrasonic welding to fix a surround to a frame. However, the ultrasonic welding has not widely and successfully been used. This is so because (1) a speaker has many components such as a magnetic circuit including a magnet, a pot yoke, and a pole piece; a frame; a spider; a bobbin with a voice coil; a diaphragm; a surround; terminals; and tinsel leads interconnecting the voice coil and the terminals, and (2) these components are made of various materials such as iron, aluminum, copper, plastic, paper, and cloth.

Applicant has found that these components are welded satisfactorily by the ultrasonic complex vibration, which provides benefits described in the second full paragraph at page 4 of the specification, reproduced as follows:

> Since a speaker is produced by using the ultrasonic complex vibration welding to some particular processes of fixing major components instead of using adhesive, the assembly and production of a speaker is accomplished under a clean circumstance at an ambient temperature, therefore eliminating thermal influence, and in good condition, whereby the productivity is significantly enhanced while maintaining a consistent and good quality. Also, since the ultrasonic complex vibration welding achieves a firm connection without thermal influence, the components welded do not suffer degradation thus providing a reliable product with a good quality.

The above described finings and benefits are not taught by the cited references.

Based on the foregoing, Sato and Kan et al., either individually or in combination, do not teach a manufacturing method of a speaker including all the limitations recited in independent claim 1 because the applied combination does not teach application of the ultrasonic complex vibration welding to a manufacturing process of a speaker. Dependent claim 2 is also patentably distinguishable over Sato and Kan et al. at least because the claim includes all the limitations

recited in independent claim 1. Applicant, therefore, respectfully solicits withdrawal of the rejection of claims 1 and 2 under 35 U.S.C. §103 and favorable consideration thereof.

Claims 1 and 2 have been rejected under 35 U.S.C. §103(a) as being unpatentable over Hecht et al. in view of Kan et al.

In the statement of the rejection, the Examiner admitted that Hecht et al. does not teach an ultrasonic complex vibration welding to fix components of a speaker to each other. However, the Examiner asserted that Kan et al. teaches the missing feature of Hecht et al., and concluded that it would have been obvious to apply the ultrasonic complex vibration welding taught by Kan et al. to Hecht et al. to arrive at the claimed invention. This rejection is respectfully traversed.

The Examiner's position in this rejection is the same as the above discussed rejection of claims 1 and 2 under 35 U.S.C. §103(a) as predicated upon Sato in view of Kan et al. Accordingly, Applicant incorporate herein the arguments previously advanced in traversing the imposed rejection of claims 1 and 2 under 35 U.S.C. § 103 for obviousness predicated upon Sato in view of Kan et al., i.e., the applied combination does not teach application of the ultrasonic complex vibration welding to a manufacturing process of a speaker.

Applicant, therefore, submits that the imposed rejection of claims 1 and 2 under 35 U.S.C. § 103 for obviousness predicated upon Hecht et al. in view of Kan et al. is not factually or legally viable and, hence, respectfully solicits withdrawal thereof.

Conclusion

It should, therefore, be apparent that the imposed rejections have been overcome and that all pending claims are in condition for immediate allowance. Favorable consideration is, therefore, respectfully solicited.

To the extent necessary, a petition for an extension of time under 37 C.F.R. 1.136 is hereby made. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to Deposit Account 500417 and please credit any excess fees to such deposit account.

Respectfully submitted,

McDERMOTT WILL & EMERY LLP

Tomoki Tanida

Tomoki Tanida
Limited Recognition No. L0098

600 13th Street, N.W.
Washington, DC 20005-3096
Phone: 202.756.8000 SAB:TT
Facsimile: 202.756.8087
Date: March 5, 2007

Please recognize our Customer No. 20277 as our correspondence address.

WDC99 1355438-1.050049.0043

CONFIGURATIONS OF ULTRASONIC COMPLEX VIBRATION SYSTEMS FOR VARIOUS APPLICATIONS IN MICROELECTRONICS

Jiromaru Tsujino, Yoshiki Harada, Shigeru Ihara, Kohei Kasahara and Norihide Sakamaki
Faculty of Engineering, Kanagawa University, Japan
tsujino@cc.kanagawa-u.ac.jp

Abstract
Newly developed three types of ultrasonic complex vibration system with a welding tip vibrating elliptical to circular locus effective for packaging in microelectronics were studied. These systems are effective for direct welding of various electronic devices without solder. The complex vibration sources are using (1) a longitudinal-torsional vibration converter with diagonal slits, (2) a complex transverse vibration rod with several stepped parts driven by two longitudinal vibration systems and (3) a longitudinal vibration circular disk and three longitudinal transducers.

Introduction

Two- or three-dimensional ultrasonic complex vibrations are effective for various ultrasonic high power applications [1]-[5]. There are no commercially available complex vibration welding systems especially for various packaging in microelectronics. Three types of ultrasonic complex vibration system with a welding tip vibrating elliptical to circular locus for packaging in microelectronics were studied.

Complex vibration are effective and essential for welding of various specimens including the same and different metal specimens, and for direct welding of semiconductor tips and packaging of various electronic devices without solder.

The configurations of the complex vibration sources are as follows,

(1) Complex vibration system using a longitudinal-torsional vibration converter with diagonal slits that is driven only by a longitudinal vibration source.Vibration sources of 27 kHz to 100 kHz were made and tested.

(2) The second system uses a complex transverse vibration rod that is driven by two longitudinal vibration source crossed at a right angle. The two driving longitudinal vibration transducers are driven two independent power amplifiers with phase difference 90°. The transverse rod has several stepped parts for amplifying vibration velocity. The systems of 40 kHz to 200 kHz were tested.

(3) The third type system consists of a longitudinal vibration circular disk and three longitudinal transducers that are installed at the circumference of the disk. The disk vibrates in almost circular locus by driving only three transducers with phase difference 60°. This vibration source is characterized by small vibration amplitude normal to the vibration surface (welding tip part). Small normal vibration is required for flip-chip bonding of a semiconductor chip with a large number of bumps on a substrate uniformly. The longitudinal vibration sources of 100, 125 kHz were tested.

Several examples of packaging in microelectronics including direct bonding of small tip parts were tested.

Configurations of three type complex vibration systems.

Complex vibration system with a longitudinal-torsional vibration converter

The 130 kHz complex vibration systems are shown in Fig.1. The 130 kHz complex vibration system consists

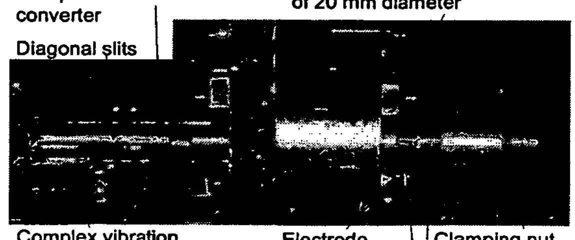

Figure 1: Configuration of a 130 kHz ultrasonic welding equipment using a longitudinal-torsional complex vibration converter with diagonal slits.

of a complex vibration converter, a stepped horn and a 20-mm-diameter BLT transducer. The complex vibration converter is driven using a longitudinal vibration system and longitudinal vibration is partially converted to torsional vibration. The free edge of the converter where four welding tips are installed, vibrates in elliptical to circular locus. The vibration locus is circular or elliptical in the case where the longitudinal and torsional resonance frequencies of the converter are almost same and the vibration phase difference of the converter is 90° or near to 90°.

Complex vibration source with a stepped complex transverse rod

The complex vibration system is shown in Fig.2. The complex vibration system consists of a stepped complex transverse vibration rod and two driving longitudinal BLT transducers crossed at a right angle. The two driving longitudinal transducers are driven using two amplifiers with phase difference of 90° to drive the welding tip in circular vibration locus. To overcome the mutual interference, the two transducers are set in bridge circuits to neglect dumped admittance of the transducers and the motional currents of each transducer are detected. One transducer is driven using a PLL auto-resonance-frequency-tracking and constant velocity control system, and the other transducer is driven with adequate phase difference of those motional currents using another driving system. Thus, the welding tip is driven in circular vibration locus that can be monitored using the

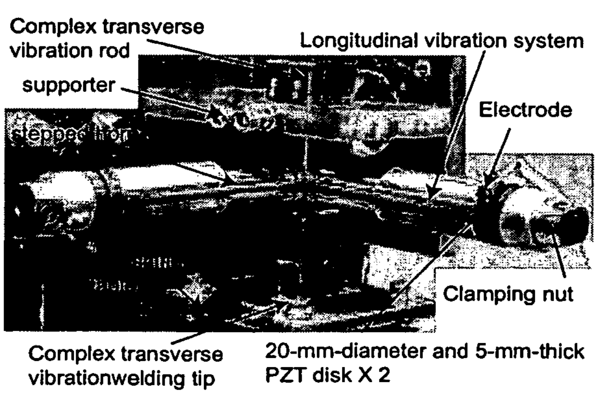

Figure 2: Configuration of a 40 kHz ultrasonic welding system using a stepped complex transverse vibration rod of 21 mm square with two stepped longitudinal vibration systems crossed at a right angle.

two motional currents of the transducers.

Complex vibration system with a longitudinal vibration circular disk

The complex vibration source consists of a longitudinal vibration circular disk with a welding tip at the center of the disk and three bolt-clamped Langevin type PZT longitudinal vibration converters of 20 mm diameter (Fig.3). The circular disk of one longitudinal wavelength diameter is driven using three longitudinal vibration transducers installed in the side circumference of the disk at 60° angle difference. The vibration source can be driven in elliptical to circular vibration locus using three amplifier with phase difference of 60° , and also can be driven by one power amplifier in the case where the transducers are arranged in sequence of the resonance frequencies.

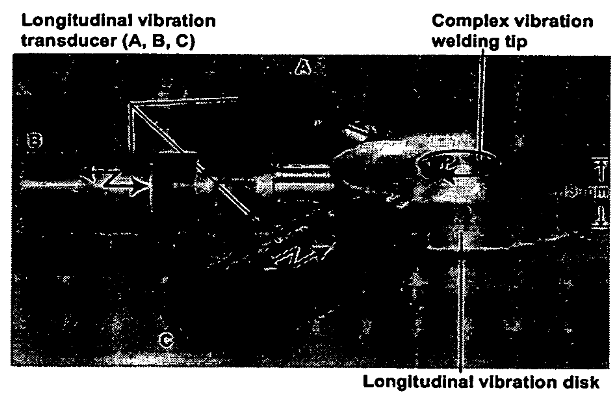

Figure 3: Configuration of a 100 kHz ultrasonic complex vibration source using a longitudinal vibration disk and three longitudinal vibration transducers of 20 mm diameter installed along the circumference of the disk.

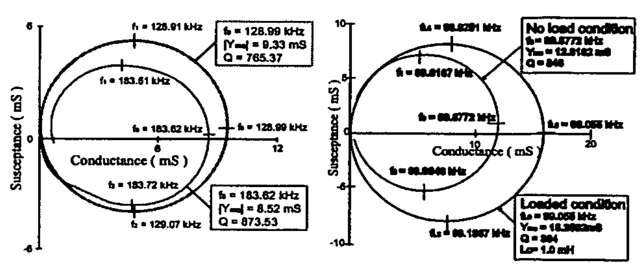

Figure 4: Free admittance loops of the 130 kHz and 180 kHz complex transverse vibration systems using a complex vibration converter measured at no load condition.

Vibration characteristics of the complex vibration systems

Free admittance loops of the 130 kHz and 180 kHz complex vibration systems (1) using a complex vibration converter with diagonal slits are shown in Fig.4. ***Quality factors*** and ***motional admittances*** of the systems are 765, 873 and 9.33 mS, 8.52 mS. The values of high-frequency 180 kHz system are larger than that of the 130 kHz system.

Transverse vibration distribution along a complex transverse vibration rod with two stepped parts of the 40 kHz system (2) is shown in Fig.5. The vibration rod vibrates in transverse vibration mode with four vibration nodes. Vibration velocity at the welding tip increases four times compared with driving position due to the two stepped parts.

Longitudinal vibration velocity distributions along the longitudinal vibration disks 20 mm and 13 mm in thickness and the welding tips of the 100 kHz complex vibration systems (3) measured at the side surface of the disk is shown in Fig.6.

Vibration loci of the welding tips of (1) the vibration systems of 128 kHz and 180 kHz, (2) the transverse vibration system, and (3) the vibration system with a disk in the cases where (a) the complex vibration system is driven using a three-amplifier-system driving equipment and (b) using a one power-amplifier-system equipment are shown in Fig.7. The vibration loci are elliptical to almost near to circular and the loci are sufficiently effective for ultrasonic welding.

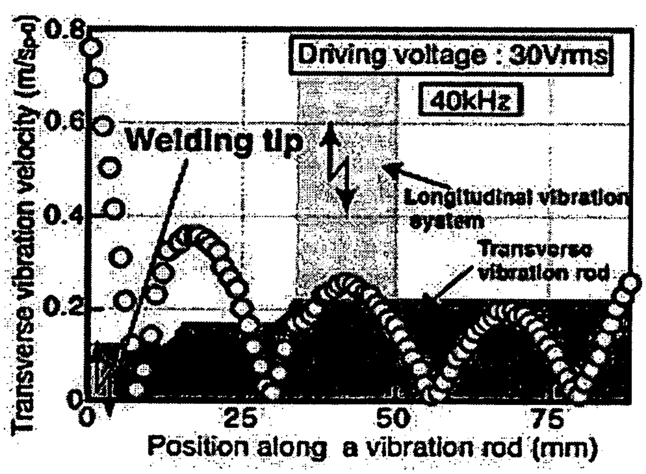

Figure 5: Transverse vibration velocity distribution along a 40 kHz stepped complex transverse vibration rod driven by two longitudinal vibration systems.

Several electronic elements welded using the complex vibration systems.

Figure 8 shows (a) a welded tip resistor on solder coated copper substrate, (b) a cross section of a tip resistor di-

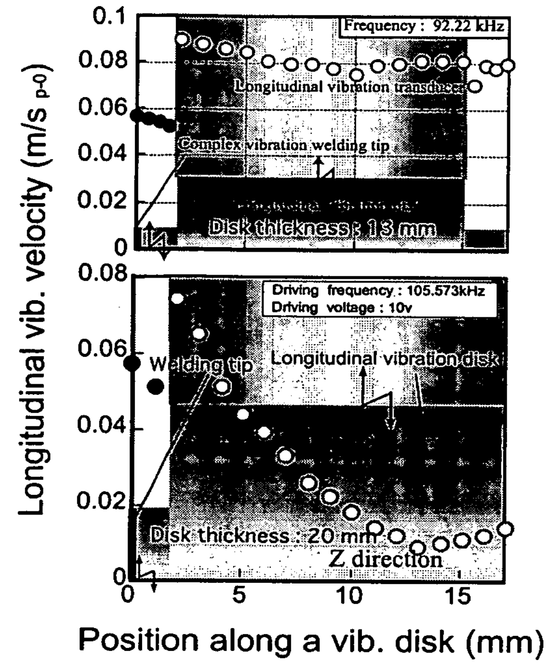

Figure 6: Longitudinal vibration distribution along the outer surface of the longitudinal vibration disk and the welding tip at the center of the disk.

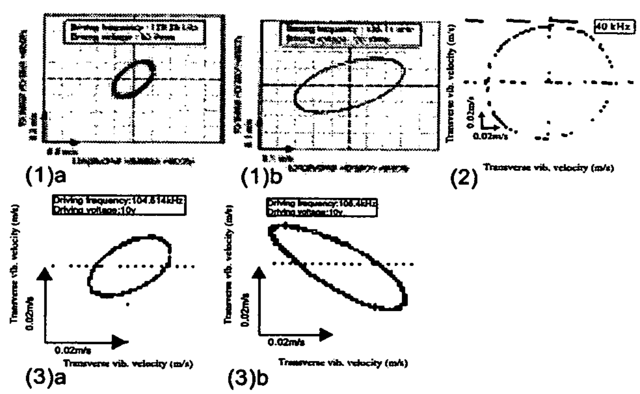

Figure 7. Vibration loci of (1) a welding tip of (a) the 128 kHz and (b) 180 kHz complex vibration system (1), (2) a welding tip of the 40 kHz complex transverse vibration rod, and (3) a welding tip of the complex vibration system (3) with a longitudinal vibration disk in the cases where the transducers are driven using one amplifier (a) and three amplifiers (3).

rectly welded on copper substrate using the complex vibration system. Electrode of the tip element was completely welded on the substrate. Figure 9 shows a welded condition of 0.5-mm-thick and 1.5-mm-wide polyester-polyimide coated flat copper wire and a nickel-plated phosphor bronze terminal.

Conclusions

Three types of ultrasonic complex vibration system with a welding tip vibrating elliptical to circular locus for packaging in microelectronics were studied.

(1)The first type systems used a complex vibration converter with diagonal slits and were driven by a longitudinal vibration source

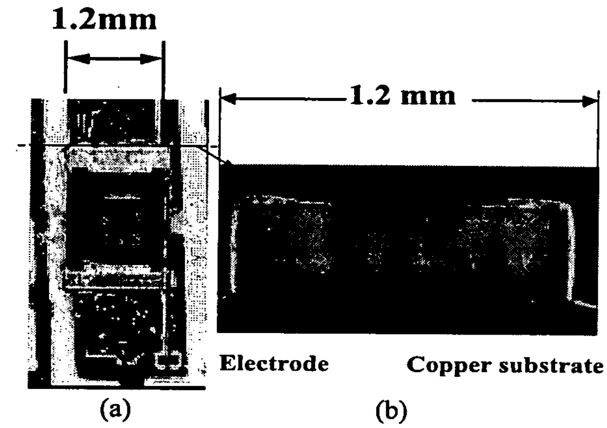

Figure 8: Welded conditions of (a) a tip resistor (1.2 mm x 2.0 mm) welded to a solder-plated substrate, (b) Cross section of a tip resistor welded to a copper substrate using a complex vibration system.

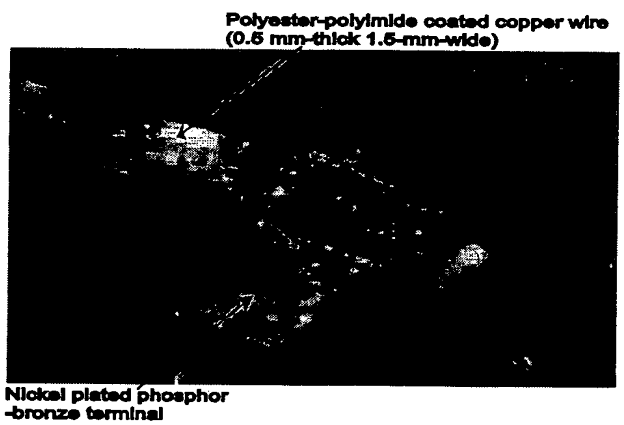

Figure 9: Welded condition of 0.5-mm-thick and 1.5-mm-thick polyester-ployimide coated flat copper wire specimens and Nickel plated phosphor-bronze terminal.

(2)The second systems used a stepped complex transverse vibration rod that is driven by two longitudinal vibration source crossed at a right angle. The large-area welding tip is installed at the free edge of the complex vibration rod. The systems of 40 kHz to 200 kHz were tested.

(3) The third type system consists of the 100 kHz and 125 kHz longitudinal vibration circular disks and six or three longitudinal transducers that are installed at the circumference of the disk. This vibration source is characterized by small vibration amplitude normal to the vibration surface (welding tip part).

It is shown that various electronic elements can be directly welded without solder (lead free) and any adhesives using the high-frequency complex vibration systems.

This work was supported by a Grant-in-Aid for Scientific Research (A) from the Ministry of Education, Culture, Sport, Science and Technology in Japan.

References

[1] J. Tsujino, K. Hasegawa, Y. Sone and K. Nozaki: frequency characteristics of ultrasonic bonding using high frequency vibration systems of 40 kHz to 780 kHz, Proc. IEEE 1996 International Ultrasonics Symposium (1997) pp.1021-1026.

[2] J. Tsujino, T. Ueoka, T. Kashino and F. Sugahara: Transverse and torsional complex vibration systems for ultrasonic seam welding of metal plates, Ultrasonics 38 Nos.1-8 (2000) 67-71.

[3] Jiromaru Tsujino, Tetsugi Ueoka and Tsutomu Sano, Welding characteristics of 27 kHz and 40 kHz complex vibration ultrasonic metal welding systems, Proc. IEEE 1999 International Ultrasonics Symposium (2000) pp.773-778.

[4] J. Tsujino and T. Ueoka: Welding characteristics of ultrasonic seam welding system using a complex vibration circular disk welding tip, Jpn. J. App. Phys. 39 No.5B (2000) 2990-2994.

[5] J. Tsujino and T. Ueoka: Welding characteristics of various metal plates using ultrasonic seam and spot welding systems using a complex vibration welding tip, Proc. IEEE 2001 International Ultrasonics Symposium (2002) pp.665-668.

CONFIGURATIONS OF LARGE CAPACITY ULTRASONIC COMPLEX VIBRATION SOURCES WITH A STEPPED COMPLEX TRANSVERSE VIBRATION ROD

Jiromaru Tsujino and Tetsugi Ueoka
Faculty of Engineering, Kanagawa University, Japan
tsujino@cc.kanagawa-u.ac.jp

Abstract

Configurations of large capacity ultrasonic complex vibration sources with multiple longitudinal transducers are proposed and studied. The ultrasonic complex vibration systems with circular and elliptical vibration locus are effective and essential for new applications in various industries. The complex vibration source of 27 kHz consists of a complex transverse rod with a welding tip (titanium alloy), a complex vibration rod with a flange and stepped part for holding the system (stainless steel), a one wavelength longitudinal vibration disk (aluminum alloy) and six bolt-clamped Langevin type PLT transducers installed along the circumference of the disk at angle 60°. Three transducer pairs installed opposite sides of the disk are driven simultaneously using three driving systems with three transformers at phase difference 120°, and the disk is driven in circular locus. The transverse vibration rod installed in the center of the disk is driven transversally and the welding tip of the transverse vibration rod vibrates in circular locus.

1. Introduction

The ultrasonic complex vibration systems with elliptical to circular locus are effective and essential for new high power applications in various industries including automobile production. As an example, ultrasonic welding of various thick metal plates becomes possible which is almost impossible using a conventional system with linear vibration, but large capacity complex vibration sources are required. It have been shown that, using a complex vibration weld tip, weld area and weld strength become larger than that obtained using a conventional system. Furthermore, weld area become uniform and also large weld strength is obtained independent of the weld position, and also ultrasonic continuous seam welding of thick metal plates are available[1]-[5].

Configurations of large capacity ultrasonic complex vibration sources with a stepped complex transverse vibration rod using multiple transducers are proposed and studied.

Transverse vibration rods were installed normally the both sides of the center parts of the circular longitudinal vibration disk (220 mm in diameter) that six 27 kHz driving longitudinal transducers (40 mm in diameter) were installed in its outer side surface at angle difference of 60°. The complex transverse vibration rod (titanium alloy: 50 mm and 60 mm in diameter) has two stepped parts for vibration velocity transformation and a welding tip.

Two transducers installed in opposite part are driven longitudinally with the same vibration phase and the transducer pair and the disk part are driven in 2 wavelengths longitudinal vibration mode using a transformer.

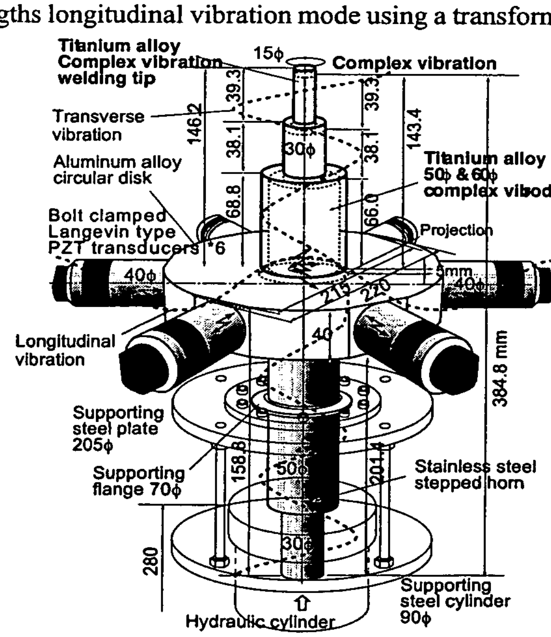

Figure 1: Configuration of a 27 kHz ultrasonic complex vibration source using six bolt-clamped Langevin type longitudinal transducers, an aluminum alloy longitudinal vibration circular disk and titanium alloy and stainless steel complex transverse vibration rods installed in the center of the disk that vibrate in circular locus.

The transverse vibration rod installed normally in the longitudinal vibration loop of the disk center is driven transversally by the transducer pair. The velocity of transverse vibration rod is amplified at the two stepped part and the welding tip vibrates in large amplitude. Each transducer pair is installed at angle difference of 120°. Three transducer pairs were driven simultaneously using three transformers, three 500 W static induction transistor power amplifiers and an arbitrary waveform generator with three output voltages of phase difference 120° and the outer and the center part of the disk are driven in circular loci. The complex transverse vibration rods installed at the center vibration loop position of the disk are driven transversally and vibrate in circular locus.
Six transducers may be independently driven directly without transformers using six power amplifiers with phase difference of 60°. The driving voltages and phase differences may be adjusted slightly to obtain circular locus in the cases where the vibration characteristics of the transducers are somewhat different
This large capacity complex vibration source may be applied effectively to welding of aluminum automobile bodies and also joining of aluminum window sashes, etc.

2. Configuration of the complex vibration source

Figure 1 shows the configuration of the complex vibration source with six bolt-clamped Langevin type PZT transducers (BLT). The complex vibration source of 27 kHz consists of a complex transverse rod with a welding tip (titanium alloy), a complex vibration rod with a flange and a stepped part for holding the system (stainless steel), a circular longitudinal vibration disk (aluminum alloy) and six bolt-clamped Langevin type PZT transducers. Transverse vibration rods were installed normally the both sides of the center parts of the circular longitudinal vibration disk (220 mm in diameter) that six 27 kHz driving BLT transducers (40 mm in diameter) were installed its outer side surface. The complex transverse vibration rod with a welding tip (50 mm and 60 mm) has two stepped parts for vibration velocity transformation and a welding tip. The complex vibration rod (50 mm in diameter) installed the opposite side of the disk is fixed in the holding system using a stepped part and a flange as shown in Fig.2. The complex vibration system is fixed to a hydraulic cylinder of a welding frame for inducing static pressure to welding specimens.

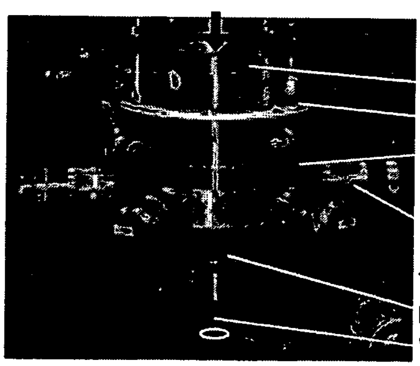

Figure 2: The 27 kHz ultrasonic vibration source fixed to a hydraulic cylinder of a welding frame using a stepped complex transverse vibration rod with a supporting flange.

3. Driving of the complex vibration source

A block diagram of the driving system is shown in Fig.3. One longitudinal transducer pair is driven in the same phase and the transducer pair and the disk vibrate in 2-wavelength longitudinal vibration mode through a transformer (transforming ratio is 1:1:1) using a 500 W static induction power amplifier. Three transducer pairs are driven simultaneously by three transformers, three 500 W static induction transistor power amplifiers and an oscillator with three output voltages of phase difference 120°. The driving voltages are $v_1(t) = V_1 \sin(\omega_0 t)$, $v_2(t) = V_2 \sin(\omega_0 t \pm 120°)$ and $v_3(t) = V_3 \sin(\omega_0 t \pm 240°)$. The direction of the circular loci is counterclockwise or clockwise according to positive or negative sign in the equation. The transverse vibration rod is driven in circular locus and almost circular vibration locus was obtained at the surface of the free edge of the complex

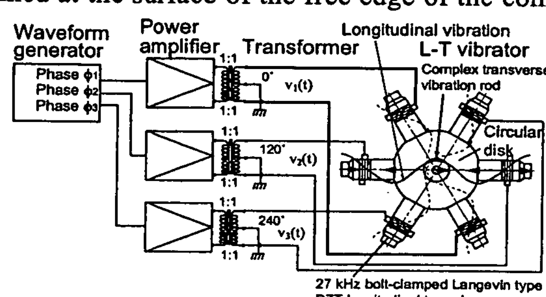

Figure 3: Block diagram of a driving system of the complex vibration source with six bolt-clamped Langevin type longitudinal transducers.

transverse vibration rod. The transverse vibration rod is driven in circular locus and almost circular vibration locus was obtained at the surface of the free edge of the complex transverse vibration rod. Driving three transducer pairs simultaneously with vibration phase difference 120°, the complex transverse vibration rod vibrates in circular locus or elliptical locus in the case where the vibration characteristics of the transducers are somewhat different. The six transducers of the complex vibration source may be driven without transformers using six independent driving systems with phase difference 60°.

4. Vibration characteristics of the complex vibration source

Transverse vibration distributions along the titanium alloy complex transverse vibration rods 50 mm and 60 mm in diameter are shown in Figs.4. One pair of the BLT transducer pair is driven. The transverse vibration rods installed at the center of the circular disk are driven normally by the center part of the longitudinal vibration disk. Driving voltage is kept at 10 Vrms. The center rods vibrate in a transverse vibration mode with four transverse vibration nodes at each side. Vibration amplitudes at the free edge of the stepped transverse rods 50 mm and 60 mm are increased 7 and 9 times by the two

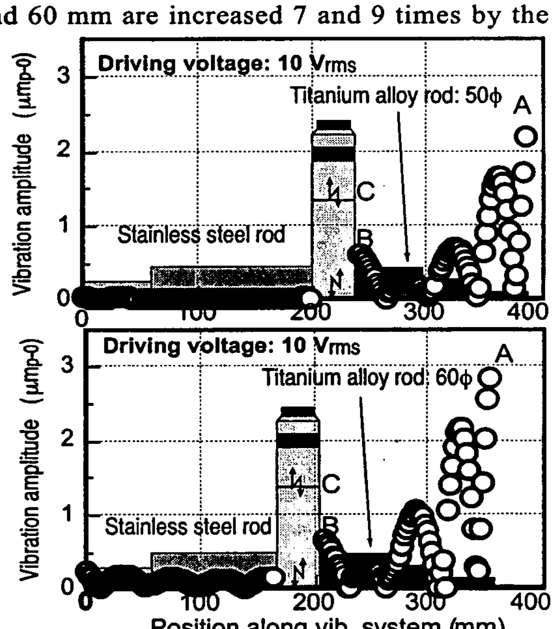

Figure 4: Transverse vibration distributions along the titanium alloy transverse vibration rod 50 mm and 60 mm in diameter and stainless steel transverse vibration rod 50 mm in diameter.

stepped parts compared with the center driving part. Vibration velocity along the stainless steel rod for supporting the system is small compared with the titanium alloy complex vibration rod with a welding tip.

Figure 5 shows the relationships between driving voltage and transverse vibration amplitude at the free edge of the transverse vibration rods made of aluminum alloy, stainless steel and titanium alloy that have two stepped parts, and radial vibration of the outer part of the disk. Vibration amplitude 12.5 μm (peak-to-zero value) is obtained at 150 Vrms in the case of the titanium alloy vibration rod 60 mm in diameter.

Figure 6 shows vibration loci at a free edge of the complex transverse vibration rod 50 mm and 60 mm in diameter in the case where three BLT transducer pairs are driven simultaneously. The vibration locus is slightly elliptical due to the difference of the vibration characteristics of the three BLT transducer pairs.

Figure 7 shows vibration distribution along the support-

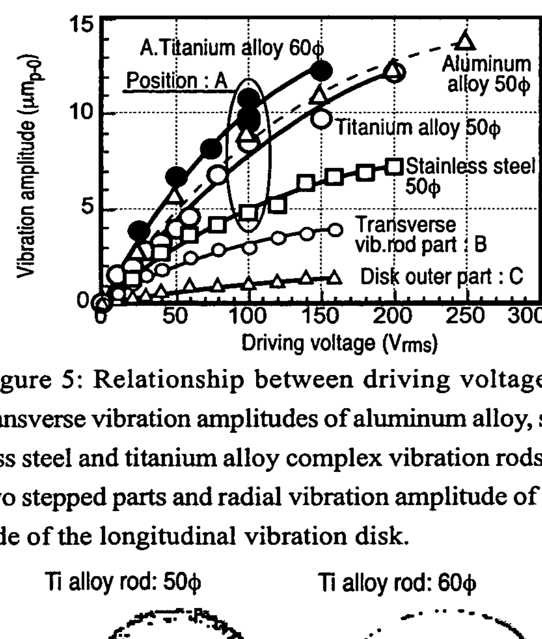

Figure 5: Relationship between driving voltage and transverse vibration amplitudes of aluminum alloy, stainless steel and titanium alloy complex vibration rods with two stepped parts and radial vibration amplitude of outer side of the longitudinal vibration disk.

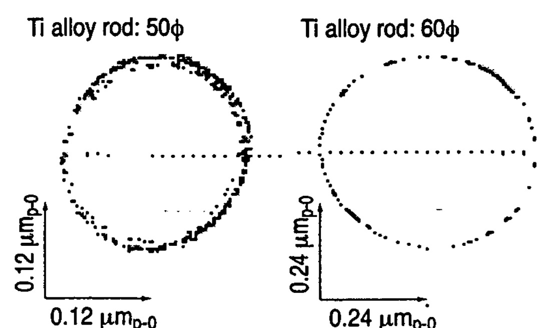

Figure 6: Welding tip vibration loci at a free edge of the titanium alloy complex vibration rods 50 mm and 60 mm in diameter.

ing flange and circular plate (205 mm in diameter). Vibration amplitude at inner part of the supporting flange decreases at outer part and vibration amplitude along the supporting disk decreases further and very small compared with that at inner part of the flange.

Free admittance loops of the complex vibration source at free condition and installed condition in supporting jigs are shown in Fig.8. Quality factor and motional admittance |Ymo| in the case where the vibration system is installed are so large as 2541 and 505.8 mS.

5. Conclusions

Configurations of large capacity ultrasonic complex vibration sources with a stepped complex transverse vibration rod using multiple transducers are proposed and studied.

Transverse vibration rods were installed normally the

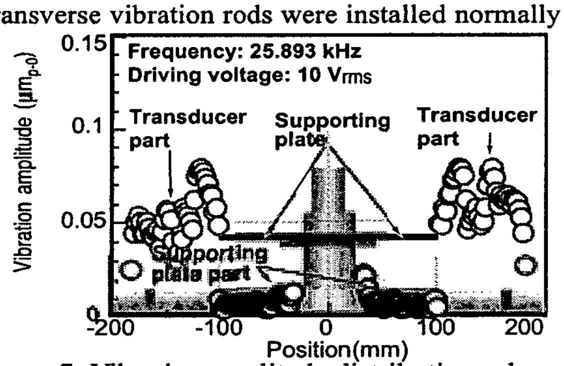

Figure 7: Vibration amplitude distributions along the flange and the supporting disk (200 mm in diameter) and the BLT transducers at frequency of 25.893 kHz. Driving voltage: 10 Vrms constant.

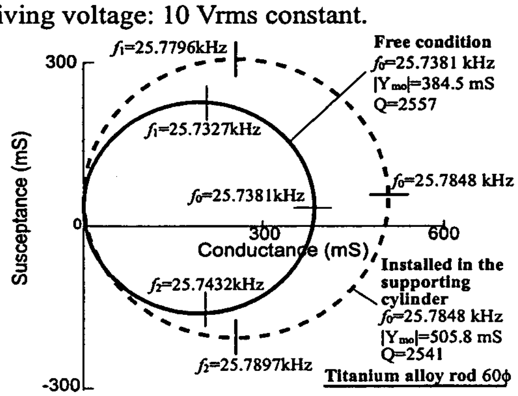

Figure 8: Free admittance loops of the complex vibration source measured from a longitudinal driving transducer pair at free condition and at installed condition in the welding frame with a fixing jigs using a steel supporting disk (20 mm n thickness and 205 mm in diameter).

both sides of the center parts of the circular longitudinal vibration disk (220 mm in diameter) that six 27 kHz driving longitudinal transducers (40 mm in diameter) were installed its outer side surface. The titanium alloy complex transverse vibration rod with a welding tip (50 mm and 60 mm in diameter) has two stepped parts for vibration velocity transformation and velocity ratio N = 7 was obtained.

Two transducers installed in opposite part are driven longitudinally with the same vibration phase and the transducer pair and the disk part are driven in 2 wavelengths longitudinal vibration mode using a transformer. Three transducer pairs are driven simultaneously using three transformers, three 500 W static induction transistor power amplifiers and an arbitrary waveform generator with three output voltages of phase difference 120°, and almost circular locus was obtained.

This work was supported by a Grant-in-Aid for Scientific Research (A) from the Ministry of Education, Culture, Sport, Science and Technology in Japan.

References

[1] J. Tsujino, T. Ueoka, T. Kashino and F. Sugahara: Transverse and torsional complex vibration systems for ultrasonic seam welding of metal plates, Ultrasonics 38 Nos.1-8 (2000) 67-71.

[2] Jiromaru Tsujino, Tetsugi Ueoka and Tsutomu Sano, Welding characteristics of 27 kHz and 40 kHz complex vibration ultrasonic metal welding systems, Proc. IEEE 1999 International Ultrasonics Symposium (2000) pp.773-778.

[3] J. Tsujino and T. Ueoka: Welding characteristics of ultrasonic seam welding system using a complex vibration circular disk welding tip, Jpn. J. App. Phys. 39 No.5B (2000) 2990-2994.

[4] J. Tsujino and T. Ueoka: Welding characteristics of various metal plates using ultrasonic seam and spot welding systems using a complex vibration welding tip, Proc. IEEE 2001 International Ultrasonics Symposium (2002) pp.665 -668.

[5] J. Tsujino and T. Ueoka: Configurations of large capacity ultrasonic complex vibration sources, Proc. IEEE 2002 International Ultrasonics Symposium (2003) pp.684-687.